RESEARCH PAPER

A Study on the Impact of SPOC-FCM Teaching Model on Student Learning Engagement and Academic Performance in University Biochemistry Courses

Yunyao Jiang[1]*, Zahari Ishak[2], Wanmeng Wu[3] and Luping Wang[4]

[1] *College of Vocational and Technical Education, College of Science and Technology, Chang Chun, China*
[2] *Faculty of Social Science and Liberal Arts, UCSI University, Kuala Lumpur, Malaysia*
[3] *School of International Education and Exchange, College of Science and Technology, Chang Chun, China*
[4]*School of Marxism, College of Science and Technology, Chang Chun, China*
[1]*1002164975@ucsiuniversity.edu.my*, [2] *zahari@ucsiuniversity.edu.my*, [3]*1002060775@ucsiunversity.edu.my and* [4]*1002164218@ucsiuniversity.edu.my*
**Corresponding Author: 1002164975@ucsiuniversity.edu.my*

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ABSTRACT

Research Objective: Based on the Kemp & Morrison model and Student Engagement Theory, this study integrates SPOC (Small Private Online Courses) with the flipped classroom to form the SPOC-FCM teaching model. This model was applied to a university biochemistry course to validate its impact on student engagement and academic performance. Research Method: This quasi-experimental study selected one class each for the control group and experimental group through systematic sampling. The control group employed traditional teaching methods, while the experimental group utilized the SPOC-FCM model. Questionnaires were administered to both groups before and after the course. Data were analyzed using SPSS 27.0. Research Findings: Compared to the control group, students in the experimental group demonstrated a highly significant increase in learning engagement ($p < 0.01$). Academic performance in the experimental group was significantly higher than that of the control group ($p < 0.05$). Conclusion: The application of SPOC-FCM in biochemistry courses can significantly enhance student learning engagement and markedly improve academic performance.

Keywords: *SPOC; Flipped Classroom; Biochemistry; Learning Engagement; Academic Performance.*

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I. INTRODUCTION

With the rapid advancement of information technology and the continuous evolution of educational philosophies, blended learning has emerged as a significant trend in higher education reform. Particularly in the context of emphasizing student-centered approaches, personalized learning, and enhanced teaching effectiveness, the integration of online and offline teaching methods has gradually become the mainstream direction for university course development [1]. As a derivative form of Massive Open Online Courses (MOOC), Small Private Online Courses (SPOC) combine the resource advantages of large-scale online courses with the deep interactivity of small-group teaching. Emphasizing “small class sizes,” “high interactivity,” and “customization,” SPOC provide a vital pathway for transforming higher education teaching models [2].

In practical teaching, SPOC leverage flexible scheduling and personalized learning support to significantly boost student initiative and engagement. Compared to traditional models, SPOC more effectively stimulate student motivation, encouraging independent study and review outside class to enhance knowledge retention [3]. In recent years, numerous universities have successfully implemented SPOC in medical, engineering, and economics courses, achieving positive educational outcomes [4]. As a foundational course for natural science and life science majors in higher education, biochemistry presents abstract content and a complex knowledge system. Traditional teaching methods often struggle to effectively stimulate student interest and comprehension. Therefore, applying SPOC to biochemistry course reform not only aligns with the trend toward information-based teaching but also contributes to improving course quality and student academic performance [5].

Furthermore, research supports the positive impact of SPOC on academic performance. Empirical studies on blended learning among medical students indicate that the SPOC model significantly enhances exam scores and knowledge transfer capabilities [3]. Similarly, research in pharmacology education has found that SPOC markedly

**Author for Correspondence: 1002164975@ucsiuniversity.edu.my*

improve student learning satisfaction and course completion rates [4]. By integrating these two key variables, one is the student engagement and academic performance, the other one is the overall educational effectiveness of SPOC blended learning can be systematically evaluated, providing a reference for future course design and teaching assessment.

Student engagement, as a core indicator measuring the quality and effectiveness of the learning process, has garnered significant attention in educational research. Studies categorize engagement into three dimensions: cognitive engagement (CE),emotional engagement (EE),behavioral engagement (BE), and , widely used to analyze students' motivation and focus during classroom learning [6]. Additional research indicates that higher levels of learning engagement correlate with improved academic performance, knowledge comprehension, and classroom satisfaction[7],[8]. In digital and blended learning environments, sustaining consistent and stable student engagement emerges as a primary instructional design objective. The modular, visual, and interactive characteristics of SPOC confer unique advantages in enhancing student motivation and participation[9].

With advances in educational technology, the flipped classroom has emerged as a key direction in higher education curriculum reform. This model emphasizes students mastering foundational knowledge through pre-class videos and independent reading, while classroom time is dedicated to discussion, interaction, and problem-solving, thereby enhancing learning initiative and deep engagement [10]. Empirical studies in recent years indicate that the flipped classroom significantly improves student academic performance, self-efficacy, and critical thinking, with particularly notable effects in medical and STEM courses [11]. Furthermore, integrating flipped classrooms with blended learning has been shown to optimize instructional design while boosting motivation and satisfaction.

As a core course for medical, pharmaceutical, and biotechnology programs, biochemistry covers complex topics like protein structure and function, enzymatic reactions, metabolic pathways, and energy conversion, demanding strong comprehension and logical reasoning skills from students [12]. However, traditional teaching often relies on lecture-based instruction, leaving students with limited engagement and practical opportunities, resulting in sub-optimal learning outcomes and low participation levels[11]. Under the SPOC model, students can pursue self-paced online learning according to their individual rhythms. Post-class activities such as classroom discussions, group collaboration, and case analysis facilitate knowledge transfer and application, thereby enhancing comprehension of abstract concepts[2].

Therefore, this study integrates SPOC with the flipped classroom, designing a novel teaching model based on the Kemp & Morrison framework. This model is applied to university biochemistry courses. Through a quasi-experimental study, we evaluate whether the SPOC-FCM approach improves learning engagement and academic performance in both the control group (traditional teaching) and the experimental group (SPOC-FCM).

II. METHOD

A. SPOC-FCM Course Design

The design of SPOC-FCM in this study comprises two parts. The first part designs the teaching model starting from Instructional Problems, one of the nine design elements proposed by Kemp & Morrison. First, the core issues that SPOC-FCM teaching aims to address must be identified, such as insufficient classroom interaction and low efficiency in self-directed learning. These should be concretely reflected in the blended teaching plan. Analyzing student characteristics and understanding their prior course foundations facilitates adjustments to the course resource model. Task Analysis is used to determine the teaching content to be completed in each class session. Subsequently, teaching objectives are categorized, knowledge points are classified, and corresponding course resources are matched based on these categories. During instruction, diverse knowledge points are presented in alternating sequences. Once these elements are established, the flipped classroom model is implemented for biochemistry course delivery.

Part Two: Flipped Classroom Design. Following the design of course format and process, a comprehensive course workflow and plan are developed. This plan undergoes evaluation by three subject matter experts. Based on expert feedback, the final flipped classroom curriculum plan and implementation process are finalized.

B. Study Design

To evaluate the effectiveness of SPOC-FCM in university biochemistry courses, this study employed a quasi-experimental research method. A "quasi-experimental" design refers to a study where participants are not randomly assigned to experimental and control groups, but the impact of an intervention or treatment on subjects is still assessed through methods such as establishing a comparison group or conducting pre-tests and post-tests[13].

C. Participants

The study subjects were students from two classes enrolled in the Class of 2024 Veterinary Medicine program at a university in Jilin Province. Inclusion criteria required students to be currently enrolled in the "Biochemistry" course that semester, studying identical course content, and proficient in using online platforms for digital learning. Exclusion criteria included: students with more than three absences during the course, prior participation in SPOC or other flipped classroom training, learning disabilities/physical conditions affecting normal learning, or those with severe data loss due to incomplete pretests or post-tests.

D. Sample size and Sampling method

As a quasi-experimental study, this research employed cluster random sampling. Cluster random sampling is a typical probability sampling method, particularly suitable for research where subjects are organized into "natural clusters" . Its core principle involves: first dividing the population into multiple relatively autonomous clusters; then randomly selecting several clusters as samples; and finally sampling all individuals within these selected clusters or choosing a sub-sample according to specific rules[14].

Therefore, from the eight classes of the Class of 2024 in the Veterinary Medicine program at a certain university, each class was numbered from 1 to 8. The researcher randomly selected one number, and the corresponding class served as the SPOC-FCM experimental group. From the remaining seven classes, one number was randomly selected, and the corresponding class served as the traditional teaching control group. Research and measurements were conducted on all students in the selected classes. The final groupings were: Class 1 as the experimental group (N=35) and Class 2 as the control group (N=35).However, one student in Class 1 has taken a leave of absence due to health reasons, resulting in an actual sample size of 34.

E. Study variables

This study involved two variables: student learning engagement, comprising three dimensions, the cognitive, emotional, and behavioral engagement; and final academic performance, represented as numerical scores. Student performance was calculated as a weighted average of both coursework grades and the final exam score, rather than solely the exam score.

F. Study Instrument

For measuring the effectiveness of student learning engagement in this study, a questionnaire survey method was employed. The questionnaire used in this study was adapted from the "College Student Learning Situation Survey Questionnaire" [15] The questionnaire comprises 21 items assessing participants' academic engagement. Based on the classification dimensions of learning engagement, itnis divided into three dimensions: cognitive engagement (Items 1-6), emotional engagement (Items 7-15), and behavioral engagement (Items 16-21). A 5-Likert scale is employed, ranging from "strongly disagree" (scored 1) to "strongly agree" (scored 5).

Within educational research, academic performance serves as a core metric for evaluating student learning outcomes and has long been a focal point. Among various methods for measuring academic performance, examination scores are the most commonly used operational variable due to their objectivity, standardization, and strong comparability. In this study, students' academic performance is assessed based on their final grades. In accordance with relevant requirements from the Jilin Provincial Department of Education, university students' grade evaluations must incorporate both formative materials and summative assessments. Following course-specific guidelines, the final grade is calculated as follows: (Average Assignment Score + Course Attendance Score)/2*30% + Final Exam Score*70%.

G. Data collection

Data collection methods and timelines varied across variables. Data on learning engagement were collected pretest via questionnaires completed by all students in both the experimental and control groups before the start of the biochemistry course. Post-test data were collected during the final teaching week of the course when students in both classes completed questionnaires again. Final course grades were determined by the instructor after the final exam, combining the exam score with other assessments conducted throughout the teaching process.

H. Data analysis

To investigate differences in the effects of various teaching models on student learning engagement and academic performance, this study employed ANCOVA and t-tests in SPSS 27.0 for data analysis.

III. RESULTS AND ANALYSIS

A. Descriptive statistics

Descriptive statistics are presented in Table I. The results indicate:

Regarding learning engagement, the pretest(Pre) results indicate that both the experimental and control groups scored at a moderately high level across all dimensions (M=3.15-4.50). However, the experimental group demonstrated higher overall pretest means than the control group across all dimensions. Regarding standard deviation, the experimental group's SD in the pretest phase were generally smaller than or comparable to those of the control group, indicating relatively smaller individual differences and a more concentrated score distribution within the experimental group.

In the post-test(Post) phase, the experimental group showed a significant upward trend in mean scores across all dimensions, while the control group exhibited slight fluctuations or declines. The experimental group's post-test means were markedly higher than the control group's across all four engagement dimensions, with particularly pronounced increases in the CE and BE dimensions.

Regarding final academic performance (AP): The control group's average score was M = 77.92, SD = 7.29; the experimental group's average score was M = 81.20, SD = 5.97. The experimental group not only achieved a higher mean than the control group but also exhibited a smaller standard deviation, indicating that the experimental group students demonstrated a higher overall academic level and a more concentrated score distribution.

TABLE I: Descriptive Statistics

Item		**Control(N=35)**		**Experimental(N=34)**	
		Mean	**SD**	**Mean**	**SD**
CE	**Pre**	3.15	0.54	3.22	0.34
	Post	3.24	0.52	4.46	0.54
EE	**Pre**	3.78	0.6	4.42	0.58
	Post	3.51	0.79	4.83	0.32
BE	**Pre**	3.96	0.77	4.5	0.54
	Post	3.59	0.86	4.81	0.28
AP	**Final**	77.92	7.29	81.2	5.97

B. Learning Engagement

Learning Engagement ANCOVA results are presented in Table II.The pairwise comparison of learning engagement results are presented in Table III. The results indicate:

Under the condition of controlling for pretest scores, a covariance analysis was conducted on the three dimensions of learning engagement. Results revealed significant main effects of group across all three dimensions: cognitive engagement, affective engagement, and behavioral engagement.

Regarding cognitive engagement (CE), the main effect of group was significant, F(1, 66) = 89.296, $p < .001$, ηp² = 0.575, with good model fit (R^2= 0.585, adj. R^2 = 0.573), while the influence of pretest covariates was not significant (p = 0.233).

For emotional engagement (EE), a significant main effect of group was found: F(1, 66) = 24.574, $p < .001$, ηp² = 0.449. The pretest covariate effect was insignificant (p = 0.581), and the model demonstrated strong explanatory power (adj. R^2 = 0.535).

Regarding behavioral engagement (BE), the main effect of group was also significant, F(1, 66) = 47.836, $p < .001$, ηp² = 0.420, while the pretest covariate effect was insignificant (p =0.295), with good model fit (adj. R^2 = 0.475).

Overall, controlling for pretest levels, the instructional model significantly influenced all dimensions of student learning engagement, with effect sizes ranging from medium to large.

Covariance analysis revealed that the experimental group scored significantly higher than the control group across all dimensions. Specifically, significant differences were observed in cognitive engagement (CE, MD = 1.205, $p < .001$), emotional engagement (EE, MD = 1.36, $p < .001$), and behavioral engagement (BE, MD = 1.152, $p < .001$), indicating that the SPOC-FCM teaching model positively promotes students' cognitive, emotional, and behavioral dimensions of learning engagement.

TABLE II: Ancova Result for Learning Engagement

Dimension	**Source**	***df***	**F**	***p***	**ηp²**	***R²***	**adj. *R²***
CE	Group	1	89.296	< .001	0.575	0.585	0.573
	CE_Pre (Covariate)	1	1.446	0.233	0.021		
EE	Group	1	24.574	< .001	0.449	0.548	0.535
	EE_Pre (Covariate)	1	0.115	0.581	0.005		
BE	Group	1	47.836	< .001	0.42	0.49	0.475
	BE_Pre (Covariate)	1	1.115	0.295	0.017		

Note: ηp² = partial eta squared.

Table III: Results of Pairwise Comparison of Learning Engagement

Item	**Comparie: Experimental-Control**	
	MD	***P-value***
CE	1.205	< .001
EE	1.36	< .001
BE	1.152	< .001

*Note: p < .05, *p < .01, **p < .001.*

C. Academic Performance

The pairwise comparison of learning engagement results are presented in Table IV. The results indicate:

An independent samples t-test was conducted to compare the AP scores between the control and experimental groups. The results indicated a marginally significant difference between the control group (M = 77.92, SD = 7.29) and the experimental group (M = 81.20, SD = 5.97), t =-2.04, p =0.05.

Table IV: Academic Performance Pairwise Comparison Results

Item	Mean±SD		t	*P-value*
	Control	Experimental		
AP	77.92±7.29	81.20±5.97	2.04	0.05

*Note. p < .05, *p < .01, **p < .001.*

IV. DISCUSSION

The differences between the experimental and control groups in pretest, post-test, and academic performance in this study clearly demonstrate the systematic impact of the intervention on students' learning engagement and academic achievement. During the pretest phase, the experimental group exhibited overall higher mean scores across all dimensions (M=3.15-4.50) compared to the control group, with standard deviations generally smaller than or close to those of the control group. This finding holds multiple implications. On one hand, it may reflect more positive initial learning attitudes and behavioral tendencies among experimental group students. On the other hand, it suggests higher internal homogeneity within the experimental group, potentially laying the groundwork for consistent intervention effects. In contrast, the control group's pretest data revealed greater individual variation. This heterogeneity likely stems from the natural diversity in students' self-directed learning strategies, motivation levels, and cognitive habits [16]. The post-test change patterns warrant particular attention. The experimental group demonstrated significant mean increases across all four engagement dimensions, while the control group exhibited minor fluctuations or even declines. This contrast strongly supports the intervention's effectiveness. Notably, the experimental group demonstrated especially pronounced gains in cognitive engagement (CE) and behavioral engagement (BE). The significant increase in cognitive engagement likely indicates the intervention effectively promoted students' use of deep learning strategies, meta-cognitive skill development, and higher-order thinking activities [17]. The substantial growth in behavioral engagement may reflect substantial improvements in classroom participation, task completion, and time management for learning [18].

The difference in final academic performance (AP) provides the most direct evidence of the intervention's effectiveness. The experimental group's mean score (M = 81.20, SD = 5.97) was significantly higher than that of the control group (M = 77.92, SD = 7.29), with the experimental group exhibiting a smaller standard deviation. This finding holds triple significance: First, the mean increase directly demonstrates the learning engagement intervention's promotion of academic achievement. This aligns with recent educational psychology research consensus on the positive "engagement-achievement" correlation [19]. Second, the experiment group's narrower standard deviation suggests the intervention may have a "leveling" effect-not only enhancing overall performance but also narrowing the achievement gap among students. This characteristic holds particular value from an educational equity perspective. Finally, the more concentrated score distribution may reflect the intervention's particular impact on the "middle-performing" cohort. This group is often overlooked in conventional teaching yet responds most sensitively to targeted interventions [20].

Learning engagement interventions may operate through multiple mechanisms. From a social cognitive theory perspective, the intervention may enhance engagement by boosting students' self-efficacy, optimizing goal setting, and providing appropriate learning strategy support [11]. Notably, different dimensions of engagement may influence academic achievement through distinct pathways. Cognitive engagement may directly impact learning outcomes by promoting deep information processing and knowledge construction; behavioral engagement may function by increasing effective study time and task persistence; while emotional engagement may indirectly affect academic performance by regulating learning motivation and resilience [7]. The pronounced improvements in CE and BE dimensions observed in this study may indicate that the intervention particularly effectively targeted these mechanisms.

After controlling for pretest learning engagement levels, this study employed covariance analysis to examine the effects of the SPOC-FCM teaching model on various dimensions of university students' learning engagement. Results showed that the experimental group scored significantly higher than the control group on post-test measures across all three dimensions, including the cognitive, emotional, and behavioral engagement, with effect sizes ranging from medium to large. This finding provides robust empirical support for the blended teaching model integrating SPOC with flipped classrooms in promoting student learning engagement within higher education contexts.

Research indicates that flipped classrooms significantly enhance students' deep learning levels, with the core mechanism being the relocation of lower-order cognitive activities to pre-class preparation, thereby freeing classroom time for higher-order cognitive activities [10]. As a small-scale, structured online course format, SPOC outperform massive open online courses in content organization and learning process control, better supporting students' self-regulated learning and sustained cognitive engagement [21]. The present findings align with those of Akhter et al. (2024), who demonstrated a significant positive impact of fully online flipped classrooms on students' cognitive engagement [22].

Emotional engagement constitutes a vital component of learning commitment, encompassing students' interest, value alignment, sense of belonging, and positive affective experiences during the learning process. This study revealed that experimental group students demonstrated the most significant improvement in emotional engagement (MD = 1.360, $p < .001$), indicating that the SPOC-FCM teaching model holds distinct advantages in enhancing students' affective learning experiences. Possible reasons include, on one hand, the short videos, online quizzes, and instant feedback mechanisms provided by the SPOC platform, which help reduce learning anxiety and enhance perceived learning control. On the other hand, cooperative learning, group discussions, and classroom interactions within the flipped classroom strengthened students' social connections and sense of classroom participation. Related studies indicate that flipped classrooms can significantly enhance student learning satisfaction and emotional engagement by increasing classroom interaction and learning autonomy [23]. Furthermore, teacher guidance and support in blended learning environments are considered key factors in stimulating positive affective responses among students [22]. Thus, the larger effect size for emotional engagement in this study may reflect students' high recognition of the overall learning experience provided by the SPOC-FCM teaching model.

Regarding behavioral engagement, the experimental group also significantly outperformed the control group (MD = 1.152, $p < .001$), indicating that the SPOC-FCM teaching model effectively promoted students' overt participation behaviors in learning activities.

These include timely completion of learning tasks, active participation in classroom discussions, and sustained commitment to study time.

Learning process data from the SPOC platform made student learning behaviors more visible while providing evidence for teachers to implement targeted instructional interventions. Research indicates that when online learning data is closely integrated with classroom teaching activities, students are more likely to form stable learning behavior patterns [24]. Furthermore, multiple empirical studies confirm that integrating SPOC with flipped classrooms significantly improves student attendance rates, assignment completion rates, and classroom interaction frequency [25][26], aligning closely with the findings of this study.

This study compared the post-intervention academic performance (AP) between the experimental and control groups using an independent samples t-test. Results indicate a marginally significant difference between groups ($t = -2.04$, $p = 0.05$), with the experimental group ($M = 81.20$, $SD = 5.97$) achieving slightly higher average scores than the control group ($M = 77.92$, $SD = 7.29$). Although the *p*-value equaled the conventional significance threshold of 0.05, indicating the result straddles the line between statistically significant and marginally significant, this trend still suggests, from an educational practice perspective, that the intervention may have positively impacted students' academic performance.

Previous research has demonstrated that interventions targeting specific learning strategies, skills, or technologies have empirical support for enhancing student achievement [27]. For instance, integrating AI-assisted learning in higher education settings improves student grades and higher-order cognitive abilities, aligning with the higher average scores observed in this study's experimental group. Applying blended problem-based learning methods in classrooms also significantly enhanced the experimental group's academic performance, yielding higher scores than the control group and demonstrating the potential of structured interventions for academic improvement [28].

In educational research, *p*-values approaching 0.05, a threshold of marginal significance, which are commonly observed in interventions with modest yet practically meaningful effects. Researchers note that while the mean score differences for certain educational interventions may not reach strict statistical significance, they still hold practical value for enhancing educational outcomes and learning motivation, particularly in small samples or short-duration interventions [27]. Similar findings indicate that goal-setting interventions, while not highly effective in boosting student learning outcomes, still demonstrate positive trends and promote reflective learning behaviors [29]. Based on existing educational intervention theories, the following mechanisms may explain the impact of this study's intervention: Enhanced learning strategies and feedback loops: Many effective interventions promote students' self-monitoring learning behaviors, thereby improving performance [30]. Research indicates that periodic testing interventions significantly improve academic performance in experimental groups, with effect sizes reaching large levels compared to traditional assessment methods [31].

Additional studies suggest that meeting diverse student learning needs through differentiated strategies enhances understanding and performance among low-achieving students, thereby elevating the overall average score of experimental groups. Such strategies have been proven to significantly improve core subject grades in basic education interventions [31]. When experimental groups employ more collaborative learning, interactive feedback, or technological support, such instructional assistance increases learning motivation and time investment, subsequently boosting performance. Empirical research indicates that collaborative learning enhances academic achievement and cognitive engagement [32].

V. CONCLUSION

This study demonstrates that the SPOC-FCM teaching model effectively stimulates student engagement and significantly improves academic performance by systematically restructuring the teaching process into “online self-directed learning” and “offline deep interaction.” This finding not only provides empirical evidence for enhancing higher education quality in the digital era but also reveals the core mechanism of technology-enabled teaching: when online resources assume the foundational function of knowledge transmission, valuable classroom time is freed to address students’ deeper psychological needs, such as competence, autonomy, and relatedness, which are facilitating a paradigm shift from passive reception to active knowledge construction.

The significant value of this research lies in offering an actionable pathway to resolve the tension between “mass education” and “personalized development” in contemporary higher education. The SPOC-FCM model demonstrates that through meticulous instructional design, technology can not only expand the temporal and spatial boundaries of teaching but also fundamentally reshape the nature of teacher-student interaction, transforming educators from knowledge disseminators into learning designers and facilitators, and students from knowledge consumers into meaning creators. This transformation holds critical significance for cultivating high-caliber talent equipped with lifelong learning capabilities and innovative thinking.

Future research may deepen in three directions: First, conducting adaptability studies across interdisciplinary and intercultural contexts to explore variations and optimization strategies for this model within different disciplinary logics and cultural backgrounds; second, integrating learning analytics technology to achieve precision and personalization in teaching interventions through multi-modal analysis of student online learning behaviors and classroom interaction data; Third, examine the impact mechanisms of this model on faculty professional development, establishing a professional development system and institutional environment that supports successful teacher transformation, thereby providing systematic support for the sustainable development of higher education teaching reform.

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